NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

PRELIMINARY INVESTIGATION INTO
THE COMPUTER-ASSISTED GRAPHIC TECHNOLOGY
FOR COAST GUARD LAW ENFORCEMENT MISSION

by

Harold B. Morton

March 1985

Thesis Advisor: Norman R. Lyons

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Preliminary Investigation into the Computer-Assisted Graphic Technology for Coast Guard Law Enforcement Mission		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1985
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Harold B. Morton		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		12. REPORT DATE March 1985
		13. NUMBER OF PAGES 70
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

video disk, Coast Guard Law Enforcement, Computer Graphics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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S/N 0102-LF-014-6601

 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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Preliminary Investigation into the Computer-Assisted Graphic Technology for Coast Guard Law Enforcement Missions

by

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MASTER OF SCIENCE IN INFORMATION SYSTEMS

from the

NAVAL POSTGRADUATE SCHOOL
March 1985

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I. INTRODUCTION

Computer technology increases our ability to store and retrieve large amounts of data. But this does not necessarily mean understanding the data stored in the computer's memory. Many managers complain that too much information presented in a haphazard way detracts from the central issues.

Large stores of law enforcement data fill the U. S. Coast Guard's computers. As enforcement efforts on marine interdiction of controlled substances increase, more data accumulates in the computers. Interviews of Coast Guard Pacific Area staff indicate that the combined efforts of U. S. Coast Guard vessels and aircraft on the West Coast gather approximately 22,000 vessel movement sightings per year. An investigator looks for patterns of activity among the 22,000 sightings. He wants to discriminate normal vessel activity from illegal or suspicious vessel activity. After analysis, ships and aircraft proceed to areas of interest and investigate suspected activity.

With better understanding of the data on hand, an analyst could use Coast Guard vessels and aircraft more effectively. More effective use of what we presently own decreases the need to purchase additional resources.

Graphical tools improve the understanding and subsequent analysis of large amounts of data. When analyzing volumes of data, trends or patterns of occurrences blur if one attempts understanding by reading the rows and rows of data. Properly designed graphic applications project the data onto a medium that summarizes the data. Patterns and trends appear readily apparent.

Commercial industry uses graphic applications for summary information. Bar charts or pie charts summarize data such as sales. Air traffic controllers use real time graphic displays to monitor and track aircraft. Without graphic capabilities, a radar screen displays only a dot representing the image of an aircraft. All aircraft appear identical on the radar screen. Keeping track of what aircraft belong to what dot becomes an unmanageable task.

Keeping track of 22,000 sightings results in an overwhelming task. Currently all sighting data reside in a database management system (DBMS) maintained by the Coast Guard. A DBMS stores and maintains the sighting data in computer storage. Due to the nature of the sighting data, a database management system provides critical service to the Coast Guard law enforcement mission. The DBMS allows an analyst to make ad hoc queries from the sighting data files. For instance, an analyst often queries the DBMS for particular vessel sightings, within a specified period, in a particular location.

The Coast Guard possesses enough information in the computer storage to begin providing more effective drug interdiction efforts. But the interface between the computer and the analysis allows little understanding of the data. Visual representation of data gives meaning to hundreds of vessel names followed by a position.

A useful Coast Guard application for analyzing large volumes of sighting data involves displaying the contacts on a large map. Contacts outside shipping lanes and known fishing areas arouse suspicion and merit further investigation. Other possible applications use interactive graphics. A computer projects a map and the contacts on its display screen. Through interactive queries, the analyst determines past histories of vessel actions based on the Coast Guard sighting data. Abnormal vessel activity appears which alert the analyst to investigate that activity more intensely.

This thesis investigates what current computer graphic technologies benefit the Coast Guard law enforcement mission. Graphic applications open many avenues for better interpretation of data. But many pitfalls lurk for the unwary. This thesis presents the advantages and disadvantages of various computer graphic technologies.

II. COAST GUARD GENERAL LAW ENFORCEMENT MISSION

This chapter applies a basic management technique: define the problem before shopping for solutions. This chapter also reviews the Coast Guard's role and objectives in the enforcement of laws and treaties (ELT) on the high seas. The Department of Transportation's report, Coast Guard Roles and Missions [Ref. 1] and the appendixes [Ref. 2], [Ref. 3], [Ref. 4] constitute the primary source of information for this chapter. For additional studies in Coast Guard law enforcement, the Maritime Law Enforcement Manual (MLE) [Ref. 5] will answer most questions. The MLE provides Coast Guard policy, law enforcment history, and references to congressional action authorizing the Coast Guard law enforcement activities.

A. DESCRIPTION OF COAST GUARD LAW ENFORCEMENT ACTIVITY

The Coast Guard's enforcement of laws and treaties (ELT) activities fall into two categories: general law enforcement and enforcement of conservation regulations. The general law enforcement program involves marine interdiction of controlled substances, enforcement of immigration laws, and other criminal activities such as vessel hijackings. Enforcement of conservation regulations concerns protection of fisheries and marine living resources.

1. Maritime Drug Interdiction

During the 1970's the drug smuggler's primary source of marijuana, a bulk commodity, came from Mexico to the U. S. over a land route. Expanded enforcement activities by both the U. S. and Mexico shifted the primary source of marijuana to Colombia. Now, during the 1980's, the smugglers bring their bulk contraband to the U.S. by sea routes.

Smuggling marijuana by sea into the U. S. involves Coast Guard jurisdiction. The Coast Guard expanded its general law enforcement activities to halt the new inflow of illegal contraband by sea. As a result, the Coast Guard's siezures of marijuana increased from 8 tons in 1973 to 1247 tons in 1980 [Ref. 6].

Congressional action during the early 1980's strengthened the Coast Guard's maritime drug interdiction efforts. Congress passed laws that amended the elements of proof necessary to prosecute trafficking cases and expanded the jurisdiction over those cases associated with smugglers. Congress passed laws allowing the Department of Defense (DOD) components to assist in general law enforcement efforts.

2. Fishery Conservation

Concern over exploitation of fish stocks off U. S. Coasts prompted enactment of the Magnuson Fishery Conservation and Management Act of 1976. Enforcement of

this act requires the Coast Guard to patrol fisheries within a 200 mile conservation zone of the U. S. coast. The law allows Coast Guard patrol vessels to board any fishing vessel to insure compliance with the 1976 Magnuson law.

3. Immigration

The Coast Guard's involvement in controlling illegal alien activity by sea shows a historic involvement. Previous Coast Guard involvement includes suppressing the slave trade during the 1810's and prohibiting entry of Chinese "Coolie Labor" during the 1860's. Until April 1980, current history shows little involvement by the Coast Guard in stemming illegal immigration.

Between April and September 1980, a massive illegal Cuban immigration to the U. S., by sea, occurred. Approximately 125,000 Cuban aliens departed Cuba for the U. S. [Ref. 7] The Coast Guard provided search and rescue support to the poorly outfitted immigrants.

During the Cuban immigration, the Coast Guard received direction to forcefully prevent U. S. ships from going to Cuba to bring back illegal aliens. Future trends indicate continued Coast Guard involvement in stemming illegal immigration.

4. Other Law Enforcement Activities

Activities that concern the U. S. Coast Guard but occur on an infrequent basis include investigating vessel hijackings, reducing fishing gear losses and preventing

illegal civil craft loitering. The Coast Guard investigates and prosecutes all known or suspected vessel thefts or hijackings occurring in federal jurisdictions. The Coast Guard's operational commitments include record keeping, intelligence gathering, information dissemination, and surveillance.

The Coast Guard intends to prevent or minimize damage to marine fishing gear. Most damage occurs as a result of interference between fixed and mobile gear users. The duties of the Coast Guard involves plotting the position of the fishing gear and disseminating the information through marine broadcasts.

Various maritime danger areas pose threats to civil craft. Danger areas include those DOD designated weapons testing zones. The Coast Guard's function includes informing vessel operations of the status of various danger areas.

B. COAST GUARD LAW ENFORCEMENT METHODS

1. Maritime Drug Interdiction

Coast Guard drug seizures occur as a result of one of three operations. The first type of seizure occurs while executing another mission. For example, drug smugglers request Coast Guard assistance during an emergency condition. When the Coast Guard arrives on scene and discovers the contraband, they make a seizure.

The second type of seizure occurs from information gained by investigative work. The Coast Guard receives such information from other law enforcement agencies or private citizens. In this type of seizure, before the vessel enters U. S. waters, the Coast Guard possesses all knowledge necessary to intercept and seize a drug carrying vessel.

The third type of seizure results from Coast Guard planes and ships patrol efforts. The planes and ships search for smugglers, inspect, identify and board the most suspicious vessels. Patrol effort produce the most seizures.

The East Coast maritime drug interdiction efforts produce significantly more seizures than the West Coast drug interdiction efforts. The East Coast maritime smuggler routes pass through identified choke points. Coast Guard ships and planes concentrate on those particular choke points attaining high interdiction rates.

No particular choke points exists on the U. S. West Coast. Consequently, fewer drug interdiction seizures occur on the West Coast.

Although no choke points exists on the West Coast, the Coast Guard expends much effort to identify suspicious activity. Numerous aircraft surveillance flights and ships patrol the sea lanes documenting all vessel sightings. These efforts produce approximately 22,000 West Coast vessel sightings per year.

The Coast Guard uses a mainframe computer to store and categorize both West and East Coast sightings. Sightings gathered from patrols may contain a vessel with a history of drug smuggling. The mainframe computer checks the vessel names for known drug involvement history. If the vessel possesses a drug involvement history, the Coast Guard uses covert surveillance to uncover any illegal activity.

2. Fishery Conservation

The U. S. Coast Guard monitors all fishing vessels within the 200 mile U. S. coastal fishing zone. All foreign fishing vessels undergo periodic inspections by the Coast Guard. U. S. domestic vessels receive inspections by local state authorities in port. History reveals a higher rate of violations by foreign fishing vessels. Consequently, the Coast Guard concentrates their efforts in monitoring the foreign fishing fleet.

National Maritime Fishing Service (NMFS) places U. S. observers on 20% of the foreign fishing fleet. Congress desires observer coverage of 100% on all foreign fishing vessels. With full observer coverage, foreign fisherman will hesitate to mis-report or under report the catch [Ref. 8].

The Alaskan fishing waters involve 92% of all foreign fishing conducted in the United States. [Ref 9] The operational units based in Kodiak, Alaska maintain surveillance on the foreign fishing fleet in Alaskan waters.

Surveillance of the foreign fishing fleet relies primarily on reports or sightings by U. S. Coast Guard planes and ships. Daily flights by Coast Guard C130's report the positions of the Foreign fishing vessels. Coast Guard ships patrolling the areas note the positions and conduct periodic boardings.

Seasonal high concentrations involve as many as 300 foreign fishing vessels in the Alaskan waters. Personnel at the U. S. Coast Guard Air Station Kodiak manually plot the positions of each foreign fishing vessel on a wall map. The plotting consumes much time and effort but it produces an effective graphical tool.

3. Immigration and Other Law Enforcement Activities

The Coast Guard handles immigration and other law enforcement activities on individual event occurrences.

C. RESOURCES NEEDED FOR THE COAST GUARD LAW ENFORCEMENT MISSION

The Appendix A of the Operating Program Plan FY 87-91 [Ref. 10] describes the required resources needed for the Coast Guard's Law Enforcement Mission. The Operating Program Plan notes that the Coast Guard possesses insufficient resources to meet all its law enforcement objectives.

The current objective requires attaining a 70% maritime drug interdiction rate. [Ref. 11] Estimates for the current

maritime drug interdiction rate indicate a 15%-20% maritime drug interdiction rate. [Ref. 12] The resource projections rely on strategies involving seizures during patrols. The Coast Guard's strategy to increase the maritime drug interdiction rate requires more ships and more planes on patrol near the smugglers' routes. [Ref. 13]

Improving the technological capabilities of the resources aids the effectiveness of the ships and planes. The new radar improves the detection probabilities during patrols. Use of the aerostat technology greatly increase the radar detection and vessel monitoring for ships. (Aerostat technology uses a tethered balloon carrying a radar antenna to increase radar range of a ship.) With the new relationship with DOD, a Coast Guard analyst could use satellite coverage to provide an over all view of vessel traffic.

D. PROBLEM IDENTIFICATION

Insufficient numbers of ships and planes constitute the primary problem of the Coast Guard to meet its objective of a 70% maritime drug interdiction rate. More effective use of available resources alleviates the disabling effect of the projected resource shortage.

Improved data analysis improves the resource effectiveness. Coast Guard ships on patrol routes that possess unusual patterns of local vessel activity need to

discriminate between legal and illegal activity. A sometimes desirable but unobtainable goal of boarding all vessels passing through choke points represent an insurmountable logistic problems.

While on patrol a Coast Guard vessel boards only three to four vessels per day. Numerous vessels pass through choke points during a particular day. Time consuming contraband searches limit the number of boardings per day. Coast Guard vessels must judiciously select the vessels to be boarded. Current plans to achieve the 70% maritime drug interdiction rate rely on increasing the number of boardings. To increase the number of boardings, the Coast Guard plans to obtain more ships and planes. Another method to increase the current maritime drug interdiction rate relies on more effective selection of the vessels to be boarded. Computer graphic technology can provide decision makers with a better ability to understand vessel activity. Consequently, a more effective selection of boardings increases the number of seizures.

Current computer technology can provide tools that enable vessel sightings to be automatically plotted onto maps. Current and accurate maps showing the patterns of vessel activity allow more judicious selection of vessels for boardings. These tools also possess the ability to use current computer data storage for a historical vessel sighting analysis.

Graphical tools provide better data analysis for all phases of the Coast Guard law enforcement effort. Maintaining computer generated graphic plots of fishing vessels provides benefit to the fisheries conservation effort. For example, overlaying fishing vessel positions on a map depicting the open or closed fishing areas provides knowledge of potential illegal activity.

Data analysis increases the productivity of the patrol efforts. Reading and comprehending the volumes of information contained in the vessel sighting reports can be a substantial obstacle to human understanding. Use of current computer graphic technology enables a data analyst to better grasp the patterns of vessel activity and to convey more information to those who have operational needs.

III. REQUIREMENTS ANALYSIS

Chapter One concluded that a pictorial representation of the vessel sighting data provides more information to the law enforcement analyst. With more information, Coast Guard managers dispatch their ships and aircraft more effectively and seize more illegal contraband. This chapter specifies the general requirements for a graphical tool that will provide such a pictorial representation of the vessel sighting data.

A. SYSTEM DEFINITION

The graphic system definition includes all characteristics including the data acquisition, processing, maintainability, expandability, and output. The following describes each part of the definition.

1. Data Acquisition

The input information for the law enforcement graphical tool includes the following.

a. Vessel Sighting Data

Vessel sighting data is derived from all aspects of the Coast Guard law enforcement mission including drug interdiction, hijackings, fisheries, and illegal immigration. Coast Guard aircraft and ships gather vessel sightings during patrols. The Coast Guard

mainframe computer located at Governor's Island, New York, stores the data. Using database management software on the mainframe, retrieval of the sighting data poses little difficulty. The data retrieval process includes the ability to select particular sightings according to desired vessel characteristics or location. Coast Guard field units access the data through 9600 baud rate telephone modems. At sites other than Governor's Island, the Coast Guard C3 computer provides the means to access and locally store selected sightings.

Characteristics of the sighting data include the following:

(1) Vessel Name

(2) Vessel Length

(3) Vessel Type

(4) Course and Speed of Vessel

(5) Vessel Position by Longitude and Latitude

(6) Time of the Sighting

(7) Vessel Activity

b. Cartography

Overlaying the vessel sighting data on a geographical map provides perspective. The graphic system must include various geographical map images. Characteristics of the geographical map images include the following:

(1) Map coverage. All U. S. coastal waters extending at least 600 miles off shore.

(2) Map resolution. Different resolutions or map scales provide different views. A data analyst needs both an overall large scale view and views of remote islands or bays. Scales should range from 5 miles per inch to 200 miles per inch.

(3) Map detail. The map should include major Coast Guard points of interest such as Coast Guard units and significant geographical locations.

c. Local Inputs

Local users need to provide data to the graphic system that reflect their unique environment. Local inputs involve local military restricted zones, position of fixed fishing gear, and current position of their Coast Guard units. Characteristics of local capabilities should include the following: the capability to depict areas of interest such as military restricted zones; to annotate specific areas or vessels of interest; and to enter and move desired points such as Coast Guard units.

2. Processing

The system modifies or processes information as it passes through the system by a series of transformations. The effectiveness of this processing partially determines the success of the graphic system. The system fails when local users ignore the system or the system exceeds economic feasibility. The following describes the characteristics of the graphic processing system.

a. Human Interface

The processing must consider the human interface. Specific parameters include the following:

(1) Response Time. Excessive delays in machine operation lose the interest of users.

(2) Operating Difficulty. Ease of operation encourages users to obtain all information possible from a graphic system.

(3) Documentation and Training. Local users must easily obtain an operating knowledge of the system.

b. Performance

The system performance must equal or exceed minimum specifications.

c. Economic Feasibility

Graphic systems currently exist that will meet the Coast Guard needs. The ranges of those cost vary from $100,000 to several million. Developing a system for the Coast Guard with current technology will result in lower costs. Assuming a graphic system will use the current Coast Guard C3 system, a target cost should not exceed $10,000 per graphic work station for an initial purchase of ten units.

3. Maintainability

The issue of maintainability should consider that Coast Guard personnel will perform all required maintenance other than repairs. Maintenance costs should not exceed 10% of the purchase cost per year. This does not include normal supply items such as paper or floppy disks.

4. <u>Expandability</u>

The Coast Guard lives in an ever changing environment. Requirements and laws change on a recurring basis. The system must exhibit flexibility for change.

5. <u>Outputs</u>

The output of the computer graphic system should consider the human interface. It should be easy for people to identify information. It should also be easy for people to obtain the information in a timely and accurate fashion. Characteristics of the output should include the following:

(1) Timely output

(2) Easy to Read

(3) Easy to Change

A picture on a Cathode Ray Tube (CRT) or permanent hard copy make up the two forms of the output. The CRT possesses the advantages of timely and easily changed pictures. A permanent hard copy map provides a record and access to users without a CRT.

Operational duty personnel need the rapid response offered by screen output to assist their decision making. High level staff officers need hard copy for briefings and detailed analysis. Also, units without access to graphic systems (such as ships and planes) need hard copy.

IV. COMPUTER GRAPHICS TECHNOLOGY

This chapter reviews the basic elements of computer graphic technology. Computer graphics provides the Coast Guard law enforcement mission with the capability of processing large amounts of data. However, the software and hardware design of a computer graphic system faces many complexities.

Major topics in this chapter include benefits of computer graphics, graphic hardware and software components, hard copy output, and video disk technology. Finally, the chapter concludes with an overview of the advantages and disadvantages of various computer graphic systems.

A. BENEFITS OF COMPUTER GRAPHICS

The cliche, "a picture is worth a thousand words", provides special meaning to graphic applications. For example, 2000 vessel sightings printed out in message format provide little information to an analyst. However, when the location of those sightings are plotted on a map the analyst easily sees the patterns of the sightings.

Computer graphics bridges the gap between man and machine. While machines manipulate, sort, and print data, graphics gives meaning to the data. Graphic applications put data into a form which a human may understand.

J. D. Foley and A. Van Dam [Ref. 14] describe some representative uses of computer graphics in the following:

(1) Business, Science, and Technology: Applications involve 2D or 3D graphs of mathematical, economic functions, histograms, bar and pie charts, project scheduling and many more.

(2) Cartography: Computer graphics produce highly accurate representations of geographical areas.

(3) Computer-aided Drafting and Design: Interactive graphics aid the design of mechanical, electrical, electo-mechanical, and electronic devices.

(4) Simulation and Animation: Movies use computer graphics to generate simulated pictures such as space wars. Flight simulators use graphics to give pilots a more realistic sense of flying.

(5) Art and Commerce: Advertisement agencies use graphics to convey their message to consumers.

B. GRAPHIC HARDWARE AND SOFTWARE COMPONENTS

Understanding basic hardware and software graphic components aids the graphic system designer in selecting an appropriate system for a particular application. J. D. Foley, A. Van Dam [Ref. 15] and Ivan E. Sutherland [Ref. 16] provide the basis for the following discussions on display and hard copy output technology.

1. Display Technology

Two basic CRT picture generation technologies exist, refresh and direct-view. When the electron beam of a CRT strikes the screen, the screen phosphor coated materials illuminate thus creating the picture. The phosphor remains illuminated for a period of time. The screen receives a

periodic refresh with another electron beam to maintain the brilliance of the phosphor. The frequency of the refresh cycle depends on the quality of phosphor. Lower forms of phosphor require more frequent refresh cycles. The refresh cycle or repainting the screen to maintain the picture increases the complexity of the display technology.

The frequency of the refresh cycles must find the balance between picture/image quality and the refresh mechanism expense. A too fast refresh cycle requires a more intricate refresh mechanism and higher costs. A too slow frequency for the refresh cycle may result in a poor graphic image due to a perceptible flicker.

The direct-view technology uses a high quality phosphor which eliminates the need for refresh cycles. Once the CRT displays a picture, it stays until erased. The elimination of refresh mechanisms significantly reduces the cost of direct-view displays. A major disadvantage occurs due to the loss of ability to selectively erase parts of a picture. When changes occur to a drawing, the entire picture requires re-drawing on the CRT.

Two broad classes of computer displays exist, calligraphic displays and raster displays. The first class, calligraphic CRT displays, use a directed electron beam to paint pictures on the CRT. The beam, like a pencil, moves from point to point on the CRT, drawing a picture with little distortion. The software support for calligraphic

display represents a simpler design due to the ease of presenting the data to the CRT. The graphic display data (the picture) storage requires no manipulation before display. The data is stored in the order that it will be drawn. However, the calligraphic display hardware represents expensive and complicated technology.

The second class, raster displays, involves technology similar to a television. The CRT display results from painting the entire screen in sequence from top to bottom and left to right in the same fashion as a television. Raster hardware CRTs represents inexpensive technology due to the similarity and abundance of television technology. However, the software support for raster technology results from a complicated and expensive effort. The picture generation does not occur in the same order as its creation. The data (the picture data) order for display results from a complicated sort from top to bottom and left to right. As in television, the raster displays must receive refresh cycles for the CRT.

Resolution of the CRT refers to the detail that a display system uses for image generation. Resolution refers to the detail available in image generation. A resolution of 1024 rows by 1024 columns represents the best interactive business resolution available using current technology. Resolution of 512 by 512 provide satisfactory business

applications. Higher resolutions indicate higher hardware costs.

Extensive processing of graphic data is required before a CRT produces a graphic image. Before a CRT receives the information, geometric computations determine the proper perspective and positioning of the graphic picture. The calculations break an image object into small parts for transfer to the CRT. A system with a 1024 by 1024 resolution possesses over one million viewing sections. The computer must compute each viewing section. This more extensive processing requires more time to compute and display a picture. The more complicated a picture, the longer it takes to generate that picture. Cartographic displays or maps require extensive processing.

2. <u>Hard Copy Output Devices</u>

Three basic methods exist for producing hard copy images: printers, plotters, and cameras. Printers provide an economical solution since most computer systems already include a printer. The resolution of a printer exhibits sufficient quality for most business functions such as flow charting or bar charts. However, most printers do not offer a color option.

Plotters provide sufficient resolution to reproduce an excellent graphic image. They often offer color options, although the color reproduction is often of poor quality. The cost of plotters increases with the size of the desired

output. The equipment for wall size output generally cost above $5000.

A significant problem with printers and plotters concerns the interface with the graphic system. Many variations of graphic software interfaces exists. Since little standardization exists in graphic software interface, difficulties frequently arise in interfacing a graphic software program to a hard copy output device. In many cases, each graphic system requires a custom designed installation.

Cameras can be used to avoid the problems associated with interfaces. A camera system takes a picture of the CRT screen and produces photographs or slides. The quality of the output corresponds to the excellent images found on the CRT. Camera systems cost from $1200 and up.

3. <u>Video Disk Technology</u>

This section describes the basic disk video technology for image processing. Video disk technology produces output similar to home video cassette recorders (VCRs). Both provide pictures on a CRT or television screen. Several characteristics separate VCRs from video disk technology; storage medium, random access, and ability to record.

A video disk stores information on a platter like a musical record. VCRs use tape cartridges for the storage

medium. A video disk player reads the data from the video disk and displays the contents on a CRT.

Video disk technology permits the player to randomly select any frame on the disk for viewing. View options include single frame viewing or several frames in sequence such as a VCR. The VCR tape technology prevents random access and accurate frame selection.

A major advantage of VCRs over video disk concerns the ability to record. VCRs possess the ability to record or write images to tape multiple times. Video disks only play back information stored on the disk. After a factory produces a video disk, the information or images stored on the video disk cannot be changed.

For further information on video disk technology, Joseph Rotello Jr. [Ref. 17] provides an excellent overview.

C. CHAPTER SUMMARY

Combining a graphic computer and a video disk system gains the advantages of both technologies. A graphic computer provides many opportunities to a user for interaction. He actively interfaces with the processing and can direct selected images for display. A disadvantage of graphic computers concerns processing complicated images, such as maps.

When a user requires complicated image processing from his graphic system, he should expect a delay before the CRT

displays the desired image. Video disk technology offers an alternative to processing complicated graphic images.

Video disk technology allows storage of complicated images, such as photographs of maps, on a video disk. When requested, the system could produce the map image on the CRT in less than two seconds. Also, the quality of the image greatly surpasses what a graphic computer could provide.

V. GRAPHIC SYSTEM DESIGN CONSIDERATIONS

An effective computer graphic system relies on good design. This chapter reviews recommended design considerations for developing a graphic system. Since a graphic system provides a critical interface between computers and people, design factors must include human interaction.

The next chapter discusses two Coast Guard computer graphic systems that users did not fully utilize. The systems provided service according to design specifications but lacked an adequate man-machine interface.

The unstandardized and complex environment of graphic systems fosters slow, unresponsive and difficult to program characteristics in graphic systems. System designers must use sound design tools for developing graphic system. This chapter reviews basic design and human interaction considerations.

A. BASIC DESIGN CONSIDERATIONS

A successful graphic computer system endures. It endures because performance does not degrade over time. W. M. Newman and R. f. Sproull [Ref. 18] indicate that three design factors influence that longevity of a graphic computer system: general purpose applications; device

independent hardware components; and high level programming languages.

A frequent error in design arises when system designers believe they know all the needs of a potential application. While they attempt to optimize the system design, certain unanticipated additions to the system typically occur that require awkward and difficult design modifications. A general purpose design exhibits the most flexibility toward subsequent modifications.

Designing a system toward specific devices restricts future growth of an application. Applications designed around a particular vendor's product limit opportunities to expand to other products as technology advances. A device independent design allows flexibility in graphic system.

The final design consideration involves the complexity of the programming language or software. The software for a graphic system should use high level graphic languages, such as Pascal. Low level languages, such as assembly language, operate more efficiently and faster than high level languages. However, assembly language programming requires many hours to program. Once created, assembly language programs resist change.

B. HUMAN INTERFACE CONSIDERATION

A graphic system without adequate human factor design falls into disuse. J. D. Foley and V. L. Wallace [Ref. 19]

provide the basis for the following discussions concerning man-machine interaction. A successful interactive system considers the limitation, capabilities, and characteristics of the human using the system. A goal of interactive systems is man and computer working together as one. Two guiding principles aid the design in reaching the goal of interactive systems; interface language and the interface psychology.

1. Language Principle

The "language" between a user and a graphic system consist of the vocabulary of displays, button pushes, light pen inputs, and joy stick movements. For effective and productive man-machine interaction, communication with the system should occur with little interference from intruding remarks from the computer concerning errors. The graphic system design must consider the user and present options easily understood by him.

2. Psychological Principle

A well designed system should avoid psychological blocks such as boredom, panic, frustration, confusion, and discomfort. Psychological blocks prevent the user from fully using a system.

a. Boredom

Improper pacing or too slow a response time from the graphic system causes user boredom. Response times depend on the inherent characteristics of the graphic

system. However, response times may vary depending on the level of psychological expectation.

Three levels of psychological expectation occur; lexical, syntactic, and semantic. The lexical level expects rapid response. For example; When a typist presses a data entry key, an character should immediately appear on the screen.

The syntactic level expect responses within one to two seconds. A user creates complete thoughts or sentences at the syntactic level.

The semantic level involves deep thought or consideration. Response times of ten seconds or more occur at this level. For example, a lengthy delay to a request to summarize a report concerning yearly data would be acceptable. Often users need the increased delay to contemplate their next course of action.

When response times match the type of action expected, users feel comfortable with the systems. In addition, proper pacing avoids the other psychological blocks.

b. Panic

Unexpectedly long delays causes user panic. The user senses a problem in the computer. For example: A user enters a request for output and the screen goes blank. Did the system accept the request? Has the system failed? What happened? Displaying the system status on the screen

provides a simple remedy. The user now knows whether he created any errors.

c. Frustration

When the user cannot communicate his desires to the system, frustration occurs. This situation occurs when an inflexible system requires specific inputs and provides little guidance. For instance; The system may crash or act unpredictably if the user inputs a misspelled request. The user may not realize he misspelled the request and experiences frustration because he does not know his error or why the computer acted as it did.

Often a user will cause an action to occur that he wishes to retract. An unforgiving system forces the user to either accept the consequences or re-create the situation that he inadvertently cancelled. Forgiving systems permit users to undo a request.

d. Confusion

When the system overwhelms the user with detail, confusion occurs. Presenting a user with many poorly defined options causes confusion. The user then cannot see the forest because of the trees.

e. Discomfort

Providing an inappropriate physical environment for a graphics work station creates discomfort for the user. Users will avoid discomfort and not use the graphic system.

C. CHAPTER SUMMARY

This concludes the discussion concerning the design considerations unique to graphic system. The need to represent large amounts of data with graphic representations will continue to grow. To meet the demand, designers must develop techniques to provide effective graphic systems that users can and want to operate.

Two critical success factors concern the functional capabilities of a system and the man-machine interface. A system may perform well according to design specifications, but, good performance does not mean users will operate the system. If users find difficulty in operating a system, they will often ignore the systems and its associated benefits.

VI. SURVEY OF COAST GUARD GRAPHIC APPLICATIONS

This chapter reviews the Coast Guard's status toward developing graphic systems for law enforcement applications. Most Coast Guard progress toward graphic applications resulted from efforts within a particular district. This chapter reviews the progress of the following Coast Guard districts (CGD): CGD1,CGD11,CGD7, and CGD12.

A. COAST GUARD DISTRICT ONE (CGD1)

CGD1 evaluated three microcomputer programs written by graduate students at Rensselaer Polytechnic Institute (RPI) for use in Coast Guard search and rescue planning. [Ref. 20] The programs used an Apple II Plus microcomputer system which includes the basic computer, containing 48K bytes of memory and two disk drives.

The three programs in evaluation covered the following areas: Display and Resource Information, Search and Rescue Planning (SARP), and Aircraft Search and Rescue Planning (ASARP). The Display and Resource Information program used the Apple II Plus graphic capabilities to generate cartographic displays. The CGD1 evaluation report indicated an unsatisfactory graphic generation response time for SAR applications.

The SARP program provided information concerning the probable location of a search object. The ASARP program provided information concerning effective use of available resources. Neither of the programs used graphics, although they provided useful and timely information to a SAR planner.

The significant point in this CGD1 evaluation concerns the negative comments concerning the graphic system's response time. This point characterizes a typical problem concerning cartographic applications. Graphics applications, such as cartographics, that require extensive processing will exhibit slow response times.

B. COAST GUARD DISTRICT ELEVEN (CGD11)

CGD11 leads the Coast Guard toward graphic development. They initiated a contract with the PANATEC INC [Ref. 21] for design and development of a graphic system. The intent of the design considered the Command, Control, and Communication role for Search and Rescue (SAR), Law Enforcement, and Marine Safety.

PANATEC designed and implemented the system during 1983. After Coast Guard officials observed a prototype in operation for one year, they requested additional modifications from PANATEC to alleviate noted disadvantages.

The PANATEC based the design of the proposed computer graphic system on the following criteria:

(1) The system should produce an annotated display of coastal and open ocean areas in the Eleventh District operating area.

(2) The system should provide plotting, accurate to .1 nautical mile of actual position of:

  (a) latitude and longitude lines

  (b) ships

  (c) aircraft

  (d) hospitals

  (e) helicopter landing pads

  (f) track lines

  (g) search patterns

  (h) ADF lines of position

(3) The system should allow for the following:

  (a) Addition or deletion of fixed points such as hospitals or helicopter landing pads.

  (b) Changes to any descriptive data such as ship's cruising range, fuel capacity or home port.

  (c) Measurement of distances between plotted positions.

After a year of observation of the system in actual use, the CGD11 project managers offer the following comments:

Advantages:

(1) Use of existing Coast Guard installed hardware.

(2) Acceptable resolution by the Coast Guard standard terminal.

(3) User familiarity with Coast Guard hardware.

(4) Human interaction with the system by cursor and mark/bound acceptable by users.

Disadvantages:

(1) Slow speed of operation: 30-45 seconds lapse before system generates a picture.

(2) Inability to zoom in on charts with less than ten percent of total picture. For example: if the chart measures 100 miles by 100 miles, the system only scales down to 10 miles by 10 miles.

(3) Redrawing the entire picture when changing the map scale.

Despite the advantages noted, the users ignored the system and its capabilities due to the long time delays for production of a CRT image.

C. COAST GUARD DISTRICT SEVEN (CGD7)

CGD7 possesses no graphic systems but indicates high interest in the development efforts by CGD11 with PANATEC. CGD7's primary interest concerns graphic applications for their law enforcement mission in Florida.

The current PANATEC system cannot interface with an external database system. CGD7 requested a proposal from PANATEC concerning a graphic system on the Coast Guard standard computer that displays targets obtained from external data bases.

D. COAST GUARD DISTRICT TWELVE (CGD12)

Coast Guard Headquarters has directed CGD12 to investigate and develop an Operations Center Automation

System (OCAS) which requires graphic capabilities. OCAS' design intends to provide decision support capabilities to the operation center personnel.

The personnel have not finalized the design for the graphic capabilities of OCAS. Their current investigation includes consideration of IBM compatible personal computers for graphics and video disk technology. The author of this thesis maintained contact with those personnel and provided information concerning video disk technology.

E. CHAPTER SUMMARY

There exists a definite ongoing interest in graphic capabilities by Coast Guard personnel. This high interest indicates a definite need for computer graphic systems. Unfortunately, no satisfactory solution for a graphic system exists in the Coast Guard at this time.

VII. EVALUATION OF ALTERNATIVES

This Chapter reviews and compares alternative approaches to providing computer graphic systems for Coast Guard law enforcement activities. The requirement analysis of Chapter Three provides the basic criteria for comparing alternatives. The alternatives consist of general hardware and software technology.

A. DESCRIPTION OF ALTERNATIVES

Three alternatives exist that offer possible remedies to the graphic needs of the Coast Guard law enforcement activities; a stand alone computer, a stand alone computer assisted with video disks, and a time shared graphic capability. The following describes each alternative in more detail.

1. Alternative One: Stand Alone Computer Graphic System

This alternative provides graphic capabilities to the Coast Guard law enforcement mission with on site computer generated graphics. A computer processor will generate all graphics including the cartographic applications. An example of such a system occurs with the Coast Guard C3 computer.

2. Alternative Two: Stand Alone Computer Graphic System Assisted by Video Disk

For this alternative, an on site computer provides graphic capabilities augmented with a video disk system providing the complicated cartographic images. This represents new but proven technology. Currently the U. S. S. Carl Vinson uses such a system. [Ref. 22]

3. Alternative Three: Graphic Capabilities through Time Sharing

This alternative requires a remote computer center with graphic capabilities. A user with a graphic terminal could access the remote computer and the desired graphic capabilities. Telecommunication links such as telephone lines provide the connection between the remote computer and the local graphic terminal.

Contracting with a remote computer center provides the benefits of a large support staff for maintenance and many software tasks. The remote computer center provides the cartographic applications for use by the local users. Often the tasks concerning software and hardware maintenance remain in the hands of the remote computer center's staff. The Defense Data Network currently operates such systems.

B. COMPARISON CRITERIA

The criterion used for comparison will rely on assigned values given to each of the alternatives based on their ability to satisfy the requirements stated in Chapter Three.

Values will range from 1 to 4 with 4 representing the best score for meeting a particular requirement.

Value assignments occur according to the following standards:

4: Insignificant or No Problems: Attainment of the requirements occurs.

3: Minor problems: The problems do not interfere with the alternative's capability to functionally perform.

2: Significant problems: Attainment of requirements may not occur with this rating. Significant problems present obstacles for effective performance by a particular alternative.

1: Major Problems: Attainment of requirement will not occur with this rating. Barriers prevent successful performance of a particular alternative.

C. COMPARISON OF ALTERNATIVES

This section will evaluate the relative merits of each alternative concerning its ability to meet the stated requirements, as outlined in Chapter Three. The alternatives will receive grades according to the previously established criterion. After investigating the relative merits of all alternatives and their ability to satisfy the requirements, a summary table will provide an overall perspective concerning a recommended alternative.

1. Requirement One: Data Acquisition

The Requirement for input involves three basic capabilities. The first capability concerns the system's ease of receiving data from external data bases such as Coast Guard maintained vessel sighting information. The

second capability concerns the quality of cartographic data. The final capability involves the system's capabilities to accept user defined inputs. The following evaluates each alternative's methods of handling the input.

a. Alternative One (Computer System)

Current methods of obtaining vessel sighting data involve a telecommunication link with the central Coast Guard data base. The user selects a small subset of the stored data before transmission. The transmission consist of an ASCII file which most general purpose computers can read and manipulate. This method of acquiring data presents few problems to a high level software language such as PASCAL.

Obtaining geographical image data for cartography applications and user designed formats present some significant problems. Such data requires a form specific to any one particular application. After implementation, a cartographic application does not easily transfer to other hardware systems. This disadvantage occurs because there exists few standards among graphic applications.

These restrictive constraints prohibits flexibility. After implementation of such a system, modifications or changes require difficult and expensive effort. This alternative receives a numerical value of 2

based on the inflexible nature of the required graphical data structures.

b. Alternative Two (Computer System with Video disk System)

The major difference of between Alternative One and Two involves the use of the video disk system. The video disk provides the cartographic data in pictorial format.

Obtaining cartographic data from the video disk system adds flexibility to a computer graphic system. The video disk system's pictorial format permits better transportability between various computers. The video disk system possesses the ability to use different computer systems or software languages.

The quality of the video disk cartographic format greatly exceeds the cartographic capabilities of Alternative One or Three. This format consists of actual high resolution visual images of maps. This alternative receives a numerical value of 4.

c. Alternative Three (Time Sharing)

The time sharing facility addresses many problems associated with the acquisition of cartographic data. The quality of the cartographic data exhibits similar qualities as Alternative One since both generate the graphics by computer processing.

A serious problem associated with time sharing systems involves user dependency, since the user possesses only one option for acquisition of cartographic data. The user's option is limited to whatever the time share system desires to offer. The particular cartographic data may not satisfy all needs. Another problem concerning user dependency involves reliance on the continuing existence of a stable time share system. Long term reliability becomes a risk.

Due to the risks associated with user dependency on a time share system, Alternative Three receives a numerical value of 3.

2. Requirement Two: Processing

Processing involves three characteristics, the man-machine interface, performance, and economic feasibility. The first characteristic, man-machine interface, depends on timely responses from a computer. If users constantly wait for results, they become bored and disinterested in the system.

The second processing characteristic, performance, concerns the ability of the system to provide required information in a timely manner. For the Coast Guard law enforcement mission, this means making available a large volume of cartographic data for frequent access by data analyst. At this point, the man-machine interface becomes

critical. If the user fails to obtain the desired information, the system fails.

The last processing characteristic, economic feasibility, concerns the costs of a particular alternative. Generally, Alternative Three (time sharing) costs more than the other alternatives primarily due to ongoing telecommunication operating costs. Alternative one and two demonstrate little difference in their costs.

The following compares the three alternatives concerning their processing abilities.

a. Alternative One (Computer System)

This alternative produces all graphic capabilities through an on-site computer system. Alternative One performs the basic functions of user interface and providing cartographic images.

A serious problem occurs with cartographic applications on Alternative One. The response time suffers due to the extensive computer processing required for cartographic applications. Current cartographic applications for the Coast Guard C3 computer exhibit response times of 30 to 45 seconds while generating a map image.

The poor response times of Alternative One adversely affects the man-machine interface. As the response of the system exceeds the user's expectation of a reasonable delay, users stop using the system.

The following cost estimates for a computer system reflect a broad generalization of the industry. Cost of a specific computer system depends heavily on the software and the level of customized design. Hardware components range in cost from approximately $5000 to $100,000. Typical software development costs range from $20,000 to $100,000.

In summary, Alternative One receives a numerical value of 2. The low value reflects the poor man-machine interface of Alternative One.

b. Alternative Two (Computer System with Video Disk)

This alternative uses an on-site computer system augmented with a cartographic video disk system. Alternative Two provides service similar to Alternative One in that they both will produce cartographic images with provisions for user inputs.

Alternative Two's speed of the cartographic processing greatly exceeds Alternative One. A video disk system can recall and present a detailed map within two seconds. Users experience minimal time delays while using a computer system augmented with a video disk. Adequate response times reduce man-machine interface problems.

Hardware costs of a computer system with a video disk system range from $6000 to $100,000. The additional video disk interface costs approximately $1500. This

alternative enjoys the lowest software costs due to the cartographic capabilities provided by the video disk system. The software costs range from $10,000 to $75,000. The final costs concern the video disks which contain the map images. Producing the video disks involves approximately $15,000 for 100 video disks.

Alternative Two minimizes problems for the processing requirement. The best characteristic of Alternative Two concerns the man-machine interface and the fast response times to produce cartographic images. Alternative Two receives a numerical value of 4.

c. Alternative Three (Time Share)

A time share system bases its processing on highly sophisticated computers located away from the local users. Alternative three functionally performs in that user inputs and cartographic images occur with little technical problems.

A significant problem concerning the man-machine interface results from poor response times. Response times suffer due to the delay attributed to telecommunication links and the type of display terminals used at the remote facility. During high load periods, a telecommunication link will bog down and provide extremely slow response for computer communication. The local terminal will appear to stop while waiting for transmissions from the remote time share system. Another cause for long response times concern

the use of direct view display terminals. Time share systems normally use direct view display terminals due to the technological nature of telecommunication. Producing images on direct view displays requires more time to create the image than Alternative Two. Times to create images vary from 30 seconds to 2 minutes or more.

While displaying an image, direct view display technology inhibits easy modification. Even when users require only minor changes to an image, the entire screen must be redrawn. Again a user must wait the 30 seconds to two minutes while Alternative Three creates another image.

Costs of time share systems require approximately $100,000 for initial development costs. Typical hardware costs range from approximately $3,000 to $5000 per local display terminal. Life cycle operating costs must include ongoing telecommunication charges for the connection to the time share system.

The long times to generate the image adversely affects the man-machine interface. Time share system receives a numerical value of 2, due to the poor man-machine interface.

3. <u>Requirement Three: Maintainability</u>

This section compares the relative ease of maintaining the three alternatives. The comparisons discuss hardware and software maintenance. Software maintenance involves periodic program changes or updates to meet a

users growing requirements in a changing environment. Hardware maintenance involves equipment upkeep and replacement due to normal use.

a. Alternative One (Computer System)

Current hardware components for small computers exhibit high reliability and require little maintenance. However, users must allow consideration for computer failures no matter how infrequent. Most vendors and manufacturers offer maintenance contracts for nominal fees.

Software maintenance involves correcting program errors and providing program enhancements or updates. Enhancement of a program occurs due to changing user requirements. Complicated structures found in cartographic software involve considerable effort to update and maintain.

Due to the high maintenance effort associated with updating cartographic software, this alternative receives a numerical value of 2.

b. Alternative Two (Computer System with Video Disk)

Alternative Two experiences identical hardware maintenance problems as Alternative One, since both use on site computer systems. Software maintenance for this alternative involves less complicated programming due to the addition of a video disk system. The video disk system eliminates the need for complicated cartographic software.

As requirements for map images change, the system will need a revised video disk. Since producing the video disk depends on outside services, some problems may occur. Alternative Two receives a numerical value of 3 due to the difficulty in upgrading video disks.

c. Alternative Three (Time Share)

The remote time share facility maintains responsibility for all hardware and software maintenance. Normally, time share system hardware maintenance occurs with little interference to users. Users often encounter some difficulty in modifying or updating software programs since they must deal with outside agencies. This alternative receives a numerical value of 4.

4. Requirement Four: Expandability

A system should maintain some flexibility for expansion. Expandability relates to the feasibility of enlarging or increasing the system capabilities. For example, the users of a law enforcement graphic system may consider expanding the capabilities to include search and rescue capabilities. The following compares the three alternatives concerning their expansion capabilities.

a. Alternative One (Computer System)

Alternative One does not exhibit characteristics conducive to expansion. The complicated cartography software program requires extensive modification for

additional features. This alternative receives a numerical value of 1.

b. Alternative Two (Computer System with Video Disk)

Expanding the capabilities of Alternative Two requires less effort due to the less complicated software structure. Moderate problems occur while expanding the cartographic data on the video disk. Minor program changes occur to accommodate the new video disk. This alternative receives a numerical value of 3.

c. Alternative Three (Time Share)

Changes to the Alternative Three criteria requires negotiation with the central time share facilities. A new contract often incurs additional developmental costs. Expanding a time share system may require as much work as initiating the original contract.

The most significant problems concerning Alternative Three results from the user dependency on the time share system. The time share system may not possess the additional resources or capabilities for expansion. Due to the problem of user dependency on the remote time share facility, Alternative Three receives a numerical value of 3.

5. <u>Requirement Five: Output</u>

The output of a computer graphic system involves the display quality, the time to produce the output, and the ability to easily modify the CRT output. Output forms

consist of the CRT display and hard copy output for staff briefings and records. The following compares the three alternatives in their ability to produce output.

a. Alternative One (Computer System)

Previous discussions emphasized the excessive time that Alternative One uses to produce a cartographic image. A computer system with special graphic processors require 30 to 45 seconds to produce a cartographic image. The quality of output provides a usable image. Labels can be added to aid users to recognize points of reference. After display of an image, manipulation of targets occurs with little difficulty.

Producing hard copy output requires either a plotter or a dot matrix printer. The size of hard copy output varies from letter size to table size.

Due to the long time to generate output, this alternative receives a value of 3.

b. Alternative Two (Computer System with Video Disk)

The best feature of Alternative Two involves the quality of the output and the short time to produce an image. The video disk provides photographs of maps for display on the CRT. The photographs contain all the detail and color of the original map used for producing the video disk. Time to display any particular map, requires less

than two seconds. Modifying the CRT image requires little effort and occurs rapidly.

Camera equipment provides an option for hard copy output. High quality images on color slides offer many benefits for staff briefings and records. However, a high quality camera system involves time consuming film developing. Polaroid cameras provide fast but low quality hard copy output. Alternative Two receives a numerical value of 4 due to the high quality of the output and the short time to produce cartographic images.

c. Alternative Three (Time Share)

The quality of the output exhibits traits similar to Alternative One. The time required to produce the output often exceeds Alternative One due to the direct view display technology and the quality of the telecommunication link. Any modifications to the image involves erasing the CRT display and starting over with another long time delay to produce an image.

Plotters often provide hard copy images for time share system. Few problems result from hard copy output when using Alternative Three (Time share). Due to the excessive time to produce CRT images, this alternative receives a numerical value of 3.

D. SUMMARY COMPARISON OF ALTERNATIVES

The following table displays the comparisons of the alternatives in a summary fashion.

REQUIREMENTS	ALTERNATIVES:		
	ONE	TWO	THREE
INPUT	2	4	3
PROCESSING	2	4	2
MAINTAINABILITY	2	3	4
EXPANDABILITY	1	3	3
OUTPUT	3	4	3
TOTALS	9	18	15

The above summary evaluation shows that Alternative Two (computer system with video disk) possesses superior characteristics over Alternative One (computer system). Alternative Two barely surpassed Alternative Three (Time Share). A factor in Alternative Two's favor involves cost. Alternative Two costs less than Alternative Three.

The following summarizes the advantages and disadvantages of the three alternatives.

1. Alternative One (Computer System)

Advantages:

(1) System under complete control of user

(2) Useful for small cartographic applications

Disadvantage:

(1) Long time to generate images

(2) Poor Man-Machine interface

(3) Difficulty to input cartographic data

(4) Inflexible to change

2. <u>Alternative Two (Computer System with Video Disk)</u>

Advantages:

(1) Short time to produce cartographic images

(2) High quality output

(3) User possesses complete control over system

(4) Less developmental effort for given cartographic applications.

(5) Excellent Man-machine characteristics

Disadvantage:

(1) Producing the video disk

(2) Expensive for small cartographic applications

3. <u>Alternative Three (Time Share)</u>

Advantages:

(1) Users uninvolved with program structure

(2) Maintenance handled by time share system

(3) Appropriate for low frequency of use

Disadvantages:

(1) User dependency on time share existence and capacity

(2) User dependency on existing cartographic data

(3) Most expensive of all alternatives

(4) Response time influenced by existing load on telecommunication links

The frequency of use increases the effect of the disadvantages of a particular system. Systems such as Alternative One, that produce images on an infrequent basis do not inhibit use. The more frequent the use, the more noticeable the time delays become in image production. For example in CGD11, a system similar to Alternative One fell into disuse due to excessive time delays while producing an image.

E. CONCLUSION FOR THE EVALUATION

Each alternative possesses value for a particular application. Matching the correct technology to the application ensures effective use for any particular alternative.

The appropriate applications for Alternative One (Computer System) concern small cartographic uses. When the requirement for maps remains small, a video disk system containing many thousands of map images does not appear cost effective. Users will accept slow response times when the need for a particular image occurs infrequently.

A frequent need to access many different map images concerns Alternative Two (Computer System with Video Disk). The video disk system provides rapid access to a large store of map data.

Users that require access to many different map images on an infrequent basis need Alternative Three (Time Share). Telecommunication costs remain low while the user possesses the ability to gain access to cartographic capabilities.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis shows that graphic capabilities will improve the man-computer interface leading to better analysis and communication of large stores of data. A computer graphic system will aid the Coast Guard in reaching the objective of interdicting 70% of the maritime drug smuggling. Effective use of current data would alleviate or reduce the need to deploy or purchase additional ships and planes to accomplish objectives in the law enforcement mission.

The advantages and disadvantages of current graphic technology provide a foundation for determining the best technology for cartographic graphic applications. While determining the best graphic technology, the final recommendation gives substantial consideration to the psychology of human interface with computers.

The computer graphic system using a video disk system proved superior to the other alternatives for Coast Guard law enforcement activities. The recommended system offers fast response and high quality output to operational users. The video disk system does not overload the capacity of the computer. In fact, it relieves the computer from the onerous task of computing cartographic data.

An area open for investigation concerns the expert systems using artificial intelligent software languages. Understanding the human mechanisms for problem solving will increase the communication link between man and compute. Expert systems assist users in decision making by referencing the predefined rules established by the users. An expert system allows a user to concentrate on more strategic decisions instead of routine operational decisions. For example, if a user needs to rapidly deploy resources to intercept a smuggler, the expert system could provide recommendations to the closest resource available for the mission.

B. RECOMMENDATIONS

The following summarizes the recommendations of this thesis:

(1) Coast Guard Headquarters should fund a pilot project for a law enforcement graphic computer system using the video disk technology.

(2) Investigation into new software technology concerning artificial languages and expert systems should be initiated.

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Preliminary investigation into the computer-assisted graphic technology for Coast Guard law enforcement mission.